

## VI.—ON CHANGES OF CLIMATE DURING THE GLACIAL EPOCH.

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*Concluding Paper.<sup>1</sup>**(Continued from the May Number, p. 222.)*

IN a former paper<sup>2</sup> I referred very briefly to the succession of glacial deposits in Switzerland. It was stated that no interglacial beds like those of Scotland and America occur in the Swiss grundmoräne. But, as every geologist is aware, Professor Heer and others have shown that the lignite-beds of the Cantons of Zurich and St. Gall are really of interglacial age, since they not only rest upon but are covered by glacial deposits.<sup>3</sup> There can be but one opinion as to the position in the series occupied by these lignite-beds; they are clearly intermediate in date between the accumulation of the old grundmoräne and the deposition of that "moraine rubbish" which marked the new advance of the glaciers.<sup>4</sup> This being the case, they cannot represent the beds that occur in the "till" of Scotland, but must belong to a later stage. If this correlation be correct, it seems to me that the Swiss beds will serve partly to fill up a great blank in our record, and help us to realize the condition of our country in the long ages that elapsed between the disappearance of the great confluent glaciers and the subsequent period of submergence, which gave rise to the "kames" and "esker-drift." This will appear probable, as I hope to show, after we have taken a glance at the glacial deposits in the north of Italy.

Every glacialist knows that where the Dora Baltea issues from the Val d'Aosta, to enter upon the plains of Piedmont, there occurs a moraine of gigantic proportions. This moraine is not only remarkable for its great size, but for the proof it affords that the mighty glacier to which it owes its origin must have crept over the surface of loose and incoherent deposits of sand and gravel without materially denuding them. The section of the moraine and underlying deposits is given by M.M. Martins and Gastaldi<sup>5</sup> as follows:

3. Terrain morainique.
2. Diluvium alpin.
1. Sables Pliocènes marins.

<sup>1</sup> For convenience of reference, the following is the order of appearance of the earlier portions of Mr. James Geikie's paper "On Changes of Climate during the Glacial Epoch."

First Paper—	GEOL. MAG.,	Vol. VIII.,	Decr. 1871,	p. 545.
Second "	"	"	" IX.,	Jany. 1872, p. 23.
Third "	"	"	" "	Febry. " p. 61.
Fourth "	"	"	" "	March " p. 105.
Fifth "	"	"	" "	April " p. 164.
Sixth "	"	"	" "	May " p. 215.

<sup>2</sup> GEOL. MAG., Vol. IX., p. 61.

<sup>3</sup> The mammalian remains associated with the lignite-beds are *Elephas antiquus*, *Rhinoceros Merktii*, Jacq., *Bos primigenius*, *Cervus elaphus*, and *Ursus spelæus*. See Die Urwelt der Schweiz, p. 497.

<sup>4</sup> GEOL. MAG., Vol. IX., p. 62.

<sup>5</sup> Bull. de la Soc. géol. de France, tom. vii., 2me. série, p. 554.

The upper deposit (3) is chiefly noteworthy for its enormous thickness, otherwise it exactly resembles the moraines of the Swiss Alps. The bed 2 also answers precisely to the Alpine diluvium described by Morlot and others. It contains no fossils, and seems to be composed of more or less rounded stones, irregularly stratified. None of the stones are scratched, and no angular blocks occur among them. Towards the upper surface of the deposit, however, erratic blocks begin to appear, and the "diluvium" then assumes the aspect of a moraine profonde. The underlying Sables Pliocènes marins contain a number of fossils, of which the following are said to be characteristic [the notes on the shells have been kindly furnished by my friend Mr. Etheridge]:

*Panopæa Faujasii* (Menard) occurs in our Coralline Crag and Red Crag, and is living in the seas of Sicily.

*Pecten jacobæus*; not known fossil in British strata; a Mediterranean shell.

*Pecten maximus* (Linn); Coralline Crag and Red Crag; Drift; living in British Seas, North Sea, and Mediterranean.

*Arca Noë* (Mont.) = *A. tetragona* (Poli); Coralline Crag and Red Crag; living in Scandinavian and British Seas, and Mediterranean.

*Murex saxatilis*; Subappennine shell; not known in Britain; living in Mediterranean.

*Murex Brandaris* = *M. triacanthus* (Gmelin); Miocene shell; said to be living in Mediterranean.

*Nassa conglobata* (Broc.); occurs in Red Crag, extremely rare; a Miocene and Subappennine species; not known in our drift; extinct.

*Nassa prismatica* (Broc.); Coralline Crag and Red Crag; not Glacial nor in any drift; lives in the Mediterranean.

*Natica millepunctata* (Lamk.) Miocene shell; lives in Mediterranean.

*Ranella levigata* (Lamk.) = *R. marginata* (Sow.) Miocene, (?) living. (Much confusion about this shell.)

Resting upon the marine sands which contain the above fossils, occurs here and there an ancient alluvium, which is believed by Martins and Gastaldi to be of older date than the alpine diluvium. This deposit has yielded remains of the Mastodon, the Rhinoceros, the Hippopotamus, etc., along with shells of such genera as *Clausilia*, *Paludina*, and *Helix*. In the paper to which I am indebted for these details, Martins and Gastaldi correlate this section with that at Dürnten, and are clearly of opinion that the Italian "alluvium with bones" is the equivalent of the slate-coal or lignite of Switzerland. But at the time their paper was written, the interglacial character of the Dürnten beds had not been ascertained. It is, therefore, possible that their opinion on this point may have undergone some change<sup>1</sup> since that discovery was announced; for, according to them, the marine sand and freshwater alluvium of the plains of Piedmont are Pliocene, and therefore preglacial. Many considerations, however, lead me to believe that the correlation of the Italian and Swiss deposits, which Martins and Gastaldi have made, need not be abandoned, notwithstanding that the Dürnten beds have since proved to be of interglacial age.

It will readily be admitted that the vast changes of climate which are indicated by the interglacial beds and associated deposits of

<sup>1</sup> In a recent memoir Gastaldi takes no notice of the Dürnten beds, and continues to describe the Italian deposits as belonging to the Pliocene. [See *Studi sulle Alpi Occidentali*; Mem. del R. Comit. Geol. d'Ital., vol. i., 1871.]

Dürnten could not be due to mere local causes affecting Switzerland alone—they must have left their mark over a wide area in Europe. It is therefore not unreasonable to expect that among the glacial deposits of Italy we ought to find some traces of former oscillations of climate. As far as I am aware, however, no such traces have yet been recognized. All that has been asserted in regard to the old Italian glaciers is simply this—that they once deployed upon the plains of Piedmont, and finally retired, leaving behind them, as marks of their ancient extent, the gigantic moraines of the Dora Baltea, the Dora Riparia, and those in the neighbourhood of Arona.

It will be remembered that one of the strongest objections to Prof. Ramsay's theory of the origin of lake-basins by glacial erosion, was the fact that the vast glaciers of Italy had actually crept upon the plains of Piedmont, without excavating any great cavity in the soft Pliocene sands.<sup>1</sup> I have always felt that this objection would have some force, if it could be shown that the so-called "Pliocene" beds which underlie the great moraines are really of preglacial age. But this is just the point which has not yet been proved. The mammalian remains in the old alluvium certainly do not prove it, neither do the shells which occur in the underlying marine sands. Of the nine species of mollusca mentioned by Martins and Gastaldi as characteristic, seven are still living in the adjoining seas, one is doubtful, and only one is said to be extinct. There is nothing, therefore, in the fossil-evidence to show that these beds are of preglacial age: as far as that goes, they might quite well belong to interglacial or still more recent times.

If interglacial beds do not now occur in the north of Italy, it is not because they never existed; their absence can only be accounted for by denudation. During that long interglacial period in Switzerland, when the colossal glaciers had shrunk back to the deep Alpine valleys, and oaks and pines clustered along the borders of the Swiss lakes, the vast glaciers of the Italian Alps must likewise have retired, and vegetation must then have followed their retreating steps towards the mountain fastnesses. When the cold returned, and the glaciers of Switzerland once more ploughed their way outwards, until they reached a point far beyond where the lignite-beds are now found, it is equally certain that this ice would creep down the Italian valleys, and might well deploy upon the plains of Piedmont, here scooping out, and there covering up with debris the aqueous deposits which had gathered in its absence. All that the last great advance of the glaciers could do would be to deepen rock-basins which had been hollowed out in the preceding cold periods of the glacial epoch, and slightly to erode and smooth valleys whose origin dates back to times incalculably more remote than even the dawn of the glacial epoch. If during the last interglacial period, when the Dürnten beds were being formed, all the great lake-basins of the Alps had been silted up, it is highly improbable that these hollows would have been again cleared out by the last extension of the glaciers. To have allowed such a silting-up by streams and

<sup>1</sup> *Antiquity of Man*, p. 313.

rivers, however, the latest interglacial period must have been very prolonged indeed; of much greater duration, in fact, than we have any grounds for believing it to have been. But what could not be effected by streams and rivers, might yet be accomplished by the sea. If while the last interglacial period endured, and the elephant and its congeners wandered along the shores of Zurich and the Lake of Constance, the north of Italy happened to be submerged to a depth of 800 feet or thereby below its present level, then it is conceivable that some of the great rock-basins at the mouths of the Alpine valleys might become filled up with marine deposits. Now this is just what I would infer did take place in the early stages of the last interglacial period, and the so-called "Pliocene sands" are the deposits which I am inclined to believe were then laid down. While the genial climate which marked the deposition of these sands continued to prevail, it would seem that the movement of subsidence which had brought the base of the Alps within reach of the waves was reversed, and the land once more appeared. Rivers then flowed over what had recently formed the bed of the sea, and deposited those alluvia in which the remains of Mastodon, Hippopotamus, etc., are entombed. As this mild period drew to a close, snow and ice again thickened in the valleys, and torrents in summer-time overspread the plains of Piedmont with great deposits of gravel—the Alpine diluvium of Italian geologists. When the glaciers once more issued from their deep valleys, they would be unable to clear away the immense deposits of diluvium and marine sand which had collected during the previous mild interglacial period. And thus it seems to me not improbable that large and deep rock-basins do really exist below the marine sands of Piedmont at those points where the valleys of the Dora Baltea and the Dora Riparia open upon the great plains.

In support of this opinion, it may be remarked that along the frontiers of the Alps, between Arona and Rivoli, there appears to be an entire absence of the *grundmoräne*, which in Switzerland extends to such a distance beyond the limits reached by the newer moraines that overlies the lignites.<sup>1</sup> It is hardly conceivable that, during the accumulation of the Swiss *grundmoräne*, the glaciers of Italy never extended further south than the ground now occupied by the great moraines. Mere difference of latitude does not enable us to get over this difficulty. We may readily admit that the Italian glaciers would be arrested in their downward course sooner than those of Switzerland; yet the vast extent of the Swiss *grundmoräne* indicates a former intensity of cold, which must needs have given rise to glaciers in Italy of even greater magnitude than those which piled up the gigantic moraines of Ivrea. If, however, it be possible to admit the interglacial age of the marine sands, etc., of Piedmont, then all our difficulties vanish, and the absence of lake-basins and older glacial deposits is at once accounted for.<sup>2</sup>

<sup>1</sup> Unless, indeed, some of those large erratics which are found upon the hills above Turin be the representatives of the older Swiss moraines. Gastaldi, however, believes them to be of Miocene age.

<sup>2</sup> When, some time ago, I communicated to my friend, Prof. Ramsay, a rough out-

In a previous paper<sup>1</sup> I remarked that we have no certain record of what transpired in Britain between the final disappearance of the confluent glaciers and the deposition of the esker-drift,—all that we can safely assert is, that “the ice had in large measure melted away from the land before submergence ensued.” We are quite sure that a land-surface existed in the British area after the disappearance of the great ice-sheets, and before the accumulation of the kames, although whether our country was continental or not, there is no evidence in Britain to show. But that such may have been the case would appear not improbable from the following considerations.

If we compare the deposits accumulated during the last interglacial period in Britain, Switzerland, and, as I have suggested, in Italy, we shall find that movements of elevation and depression have affected the northern and southern regions of Europe alternately. This will be seen at a glance when the separate sections are placed side by side. The series are arranged in descending order:—

<i>Britain.</i>	<i>Switzerland.</i>	<i>Italy.</i>
3. Moraines, brick-clays, and erratics: <i>Land and Sea.</i> [Cold Conditions.]	3. Moraines: <i>Land.</i> [Cold Conditions.]	3. Moraines: <i>Land.</i> [Cold Conditions.]
2. { <i>b</i> Kames, sand and gravel: <i>Sea.</i> <i>a</i> ? River deposits, etc. <i>Land.</i> [Mild Conditions.]	2. Lignite beds: <i>Land.</i> [Mild Conditions.]	2. { <i>b</i> Old alluvia: <i>Land.</i> <i>a</i> Sand, etc. <i>Sea.</i> [Mild Conditions.]
1. Glacial deposits.	1. Glacial deposits.	1. Probably glacial deposits.

Many facts seem to show that any considerable subsidence of the earth's crust in one region will be accompanied by a corresponding elevation in some other area; or, to put it the other way, elevation in one place will be accompanied by subsidence in another. If this view be not unreasonable, it is, to say the least, quite possible that while the north of Italy was being slowly depressed, the British area was being as gradually upheaved. It is true we do not know at what elevation Italy stood above the sea before the depression began, nor can we be quite certain as to the line eventually reached by the waves along the flanks of the Alps. But the subsidence probably did not greatly exceed 800 feet or thereby below the present level of the Mediterranean; and we shall perhaps not be deemed extravagant if we assume that before the land began to sink it was at least not less extensive than it is now. Returning to Britain—it would not be difficult to show that even after the deposition of our kames had commenced Scotland stood at a level relative to the

line of these suggestions, I was pleased to hear from him that he had long been of opinion that the plain upon which Aosta stands is an old rock-basin filled up with alluvium, and that there are others of the same kind between that and Ivrea. “These are common,” he says, “in many of the great Alpine valleys, and in Cumberland they are very frequent.” [Similar phenomena, I may add, occur in Scotland.] There is no reason, Prof. Ramsay thinks, why the old ossiferous alluvium described by Martins and Gastaldi, should be called *Pliocene*, and perhaps as little for referring to that period the marine sands with shells. These beds might be of the same age as the Cromer Forest bed, or even much younger.

<sup>1</sup> GEOL. MAG., Vol. IX., p. 23.

present coast-line not much below where it stands now. But to adduce proof of this would lead me into too much detail, and I shall therefore take the liberty of assuming that before the process of subsidence commenced in Italy, the shores of that country and of Britain occupied very much the same position as at present. It is evident, on the hypothesis referred to above, that long before the interglacial submergence in Italy (so-called pliocene beds) could reach its climax, Britain would become continental. An elevation of only 120 feet or thereby would be sufficient to effect a junction; and even if the upheaval in Britain reached but half the extent that the subsidence ultimately attained in Italy, the sea must have well-nigh vanished from the bed of the German Ocean and the English Channel at a time when the waves were washing the base of the Italian Alps. Such a continental condition would probably endure for a lengthy period, to be measured by the time required for the subsidence of Piedmont, the accumulation of the so-called "Pliocene sands," and the partial re-elevation of the land. For if, during the subsidence of Piedmont, Britain became continental before that downward movement was completed, our country would continue in the same condition for some time even after the re-elevation of Italy had begun. But as Italy mounted higher and higher, the sea would gradually steal in between Britain and the Continent until complete insulation was brought about. Thereafter, the subsidence in Britain continued until the Welsh mountains were laved at a height above the present coast-line of not less than 1400 or even 2000 feet. With such excessive depression in the north of Europe—a depression that brought the sea over a large part of Scandinavia, Russia, Germany, Denmark and Holland—it may be inferred that the elevation in the south of Europe raised far above the sea-level grounds which now lie drowned in the Mediterranean.<sup>1</sup>

In the early stages of this period of elevations and depressions the climate would appear to have been mild and genial all over Europe; indeed, it is very doubtful whether any glaciers existed in Britain at this time. For the climate of the last interglacial period may fairly be inferred to have been as genial as the succeeding glacial period was cold. It was under such conditions that the Elephant, the Rhinoceros and other extinct mammalia inhabited Switzerland. Then, too, Man and the great pachyderms (Rhinoceros, Hippopotamus, etc.) may have crossed into Britain—but not for the first time. Some portion of the English river-gravels and cave-deposits I would therefore refer to this period. Of course I am aware that no traces of this old land-surface have yet been detected underneath the kames of Scotland. But as the very presence of these deposits presupposes great denudation, the absence of any traces of a land-surface is hardly to be wondered at. In this connexion, however, I would refer to the peat (with palæolithic implements and bones of the

<sup>1</sup> If the upheaval in the south of Europe at all equalled the depression in the north, it can hardly be doubted that there would be land communication between Africa and Europe—the soundings between Sicily and Cape Bon indicating the presence of a submarine ridge within less than 100 fathoms from the surface.

cave-bear), which Prof. Nilsson describes as underlying the Järavall—a great ridge of sea-gravel extending “along the coast of the Baltic from Ystad to the part between Trelleborg and Falsterbo.” If this ridge be an åsar (as from the description may be inferred), and should it prove to belong to the great åsar series, this would demonstrate that man had inhabited Sweden before the last great submergence and period of floating-ice.

Before leaving the subject of the superficial deposits of Italy, it may be remarked that in the marl-beds and morainic turbaries of Piedmont, the most ancient relics of man yet detected belong to the neolithic and bronze periods—the Italian *palafitte* answering precisely to the Swiss *pfahlbauten*. The animal-remains associated with the palafitte, are the dog, pig, horse, ox, goat, sheep, stag, roebuck, boar, bear (*Ursus arctos*), etc. In none of the peat-mosses, alluvia, or marl-beds, which are clearly of later date than the moraines, have any of the old pachyderms occurred; these have only been met with hitherto in caves and in deposits of older date than the moraines and the “Alpine Diluvium” upon which these latter rest.<sup>1</sup>

Similarly, as regards Switzerland, the alluvium that fills up depressions in the morainic deposits, or otherwise occupies positions which show it to be of postglacial age (that is, of later date than the last great advance of the glaciers), contains none of the “Quaternary” mammalia, but an assemblage of fossils similar to that of the marl-beds and morainic turbaries of Italy. The Dürnten beds, with elephant and rhinoceros, occupy, beyond question, an interglacial position—they rest upon and are clearly covered by glacial deposits.

In Scotland and Scandinavia similar phenomena recur. None of the pachyderms are found in any postglacial bed; but underneath the till, and in interglacial beds, in the former country, we get the mammoth, the reindeer, the urus, the horse, and the Irish deer; and in the latter country we find bones of the cave-bear along with palæolithic implements imbedded below deposits which are probably the equivalents of our kames.

The marl-beds, alluvia, and peat-mosses of Northern Europe, like the equivalent deposits which overlie the later glacial accumulations of Italy and Switzerland, have only yielded relics of the neolithic, bronze, and iron periods.

I would also remind the geologist of the very remarkable distribution of the Quaternary mammalia in high latitudes of Asia and North America. All the great rivers of Northern Asia, from the borders of Europe to Behring's Straits, appear to flow through alluvial deposits, which are often literally packed with the remains of mammoth, Siberian rhinoceros, etc. Similar fossils are met with, but not so abundantly, on the banks of several rivers in Alaska. But in the northern latitudes east of the Rocky Mountains no such mammalian remains have been detected. According to Sir J. Richardson, “none have hitherto been found in Rupert's Land, though the annual waste of the banks of the large rivers and the frequent land-slips would have revealed them to the natives or fur

<sup>1</sup> Gastaldi, Lake Habitations and Prehistoric Remains in Italy.

traders had they existed even in small numbers. They are rare, also, or altogether wanting, in Canada; but in the valley of the Mississippi the bone-licks are well known as most extensive, and furnishing the remains of a different series of extinct quadrupeds."<sup>1</sup> In Michigan, which is fairly within the glaciated region of North America, mammalian remains are only met with in what appear to be interglacial deposits: at all events, the deposits referred to overlie and are covered by glacial accumulations. The great "bone-licks," to which Sir J. Richardson alludes occur beyond the southern limits of the "Northern Drift."

Thus it will hardly fail to strike one as remarkable, that remains of the extinct mammalia are either altogether absent from, or very sparingly present in, regions which give evidence of having been subjected to more or less intense glaciation, or are covered by deep accumulations of the later glacial drifts. In Britain, Italy, and Switzerland alike the old ossiferous alluvia, when traced from the low grounds to the mountains, disappear as soon as the moraines and "alpine diluvium" are reached. Nowhere in morainic turbaries or alluvium which can be demonstrated to be of postglacial age do any traces of the extinct pachyderms appear. But these, when they do occur in glaciated or drift-covered regions, are invariably embedded in infraglacial or interglacial deposits. It is so in Scotland, and (if the Jära-wall be one of the *åsar*) in Scandinavia also. The same rule seems to hold good with respect to Asia and North America. The great plains of Siberia never could have nourished glaciers. We cannot conceive that even during the most intense cold of the glacial epoch, conditions similar to those which characterized Scandinavia and Scotland could have existed in Northern Siberia: the absence of high-grounds and the comparative dryness of the climate must have prevented any accumulation of glacier-ice. Nor can I learn that marine deposits, similar to our boulder-clays and esker-drift, cover any portion of Northern Asia. If cones and mounds of sand and large erratics,<sup>2</sup> like those of North America, occurred in Siberia, travellers would hardly have failed to mention them. But all this is changed when we pass into the corresponding latitudes of North America east of the Rocky Mountains. There the observer encounters the marks of glaciation everywhere—everywhere, too, are great deposits of clay and boulders, mounds and ridges of sand and gravel, and huge erratics. And all over this wide area, down to the borders of the United States, the extinct mammalia never appear in any postglacial deposits. In the neighbourhood of the great lakes they occur in freshwater clays, along with abundant vegetable remains, and these clays are overlaid by glacial beds. It is only when the southern limits of the "Northern Drift" are approached, that the extinct mammalia begin to be found

<sup>1</sup> Journal of a Boat Voyage through Rupert's Land, vol. ii., p. 210.

<sup>2</sup> Middendorf told Sir C. Lyell that he had observed erratic blocks in strata of clay and sand at about fifteen feet above the sea in lat. 75° 15' N., near the river Tamyr. (Principles, vol. i., p. 185, tenth edit.) But these erratics were probably carried down by river-ice.



QUATERNARY DEPOSITS OF THE BRITISH ISLANDS, WITH SOME OF THEIR EQUIVALENTS IN OTHER COUNTRIES.				
	DEPOSITS.	FOSSILS.	PHYSICAL CONDITIONS.	FOREIGN EQUIVALENTS.
Recent Period.	1. Alluvium, Peat, Raised Beaches.	1. Sub-fossils.	1. Partial re-elevation, the Present.	1. Alluvium, loam, marl, peat, bog-iron ore, calcareous tufa, &c.
Post-Glacial Period ...	2. Peat, buried forests, river and cave deposits, in part.	2. Relics of Man; recent and extinct, or no longer indigenous mammalia, <i>Reindeer</i> , <i>Megaceros</i> , <i>Hibernicus</i> , <i>Bos primigenius</i> , <i>B. lon-gifrons</i> .	2. Continental Condition of British Islands followed by partial submergence; seasons towards close of this period more marked than at present; in the earlier stages climate more severe than now; Neolithic man; and passage to bronze and iron periods.	2. Denmark—Peat and buried trees in part. Kjolken-middings. Switzerland—Pfalzbanten. France, Belgium, &c.—River and Cave deposits in part, with reindeer, aurochs, &c. Italy—Palafitte, &c. Neolithic man, passage from stone to bronze and iron periods.
	3. Raised Beaches, &c.	3. Littoral shells, &c.	3. Elevation of the land; climate cold-temperate.	3. Scandinavia—Raised Benches.
	4. Valley Moraines and river gravels (diluvium), river gravels in South of England.	4. Arctic Mammalia, Mammoth, Siberian Rhinoceros, &c.	4. Local Glaciers in Mountain Valleys; land probably rising.	4. Germany—Terminal Moraines in Black Forest and the Vosges; loess of the Rhine and Neckar in part, with <i>Elephas primigenius</i> , <i>Rhinoceros tichorinus</i> , &c. France and Belgium—River and cave-deposits in part.
Last Glacial Period ...	5. Sand and Brick Clay.	5. Boreal and Arctic Shells.	5. Arctic Climate; land of less extent than now, but gradually rising.	5. Scandinavia—Sand and Clay, with Arctic shells. Switzerland—Moraines overlying older glacial and inter-glacial deposits; alpine diluvium, &c. France, Belgium, &c.—River and Cave deposits with Arctic Mammalia; Mammoth, Siberian Rhinoceros, &c.
	6. Erratic Blocks and earthy debris	6. No fossils.	6. Period of floating ice; land deeply submerged, but rising.	6. Scandinavia, Denmark, and Northern Europe generally—Erratics. Switzerland—Great extension of Glaciers; terminal Moraines. Italy—Moraines of Rivoiti, Ivrea, &c. France and Southern Europe—River and Cave deposits, with Arctic Mammalia and palaeolithic implements.
	7. High Level Beaches and Marine Drift.	7. Shells indicating a somewhat cold sea.	7. Submergence of the land to a depth in Wales and Scotland of about 2000 ft.; land south of the Thames not submerged (?); climate passing from temp. to Arctic; land rising.	7. Scandinavia—High-level Marine Drifts. Switzerland and Italy—Advance of Glaciers; older Alpine diluvium. France and Southern Europe—River and Cave deposits

The Glacial Epoch.

The Glacial Epoch.	Last Inter-Glacial Period ...	8. Kames, Eskers, &c.	8. Land sinking; climate temperate.	8.
Great Cycle of Glacial and Inter-Glacial Periods ...	9. Cave Deposits; river gravels, &c. in part.	9. Palæolithic implements; extinct and no longer indigenous mammals; hippopotamus, rhinoceros, elephant, &c.; mammoth, Siberian rhinoceros, &c.	9. Britain at first insular with cold climate; next continental with climate changing from cold to temperate and genial, and again to temperate; the early stages of continental conditions; the Arctic Mammals invade Britain, subsequently these disappear, and are succeeded by the hippopotamus &c., after which submergence ensues and insular conditions perhaps effected before the climate again becomes suited to Arctic Mammalia.	9. Scandinavia—Peat, with palæolithic implements and cave-bear below Jussell (?) Svalbard—Dünen beds with <i>Elephas antiquus</i> , <i>Rhinoceros Merktii</i> &c. Italy Ossiferous Alluvium of Piedmont; Marine Sands (so-called Pliocene) of Piedmont. Europe generally—Cave and River deposits, with palæolithic implements, and extinct or no longer indigenous mammalia.
	10. Moraine rubbish and "Diluvium."	10. No fossils.	10. Arctic Conditions passing away; Local Glaciers.	10. Switzerland—Moraine rubbish. Formation of loess in river valleys generally = fine glacial silt.
	11. Boulder - earth and clay of marl-timedistricts, (in inland parts. Till with no fossils.)	11. Arctic Shells in part.	11. Arctic Climate; Mountainous parts of Britain covered with snow and ice. Glaciers cease to be confluent.	11. Switzerland—Grundmoräne in part. Scandinavia—Stony clay in part.
Pre-Glacial Period ...	12. Till and Boulder-clay with intercalated and sub-jacent beds of silt, sand, clay, gravel, &c.; cave deposits; river gravels, &c.	12. Arctic Shells in part; oak, birch, pine, hazel, alder, willow, &c.; extinct and no longer indigenous mammals, both of Arctic and Southern forms; Palæolithic implements.	12. Intense Glacial conditions with great confluent glaciers; intermediate mild and warm periods; Arctic and Southern Mammalia visit Britain alternately, according as climatal conditions become suited to their needs.	12. Scandinavia—Upper and lower Stony clay, with underlying gravel and sand. Switzerland—Grundmoräne. Europe generally—River and Cave deposits, with palæolithic implements and Arctic and Southern Mammalia.
	13. Norwich Crag.	13. <i>Elephas, Mastodon</i> , &c.; some northern species of shells.	13. Indications of approaching cold.	13. †

in any numbers at the very surface; and their remains occur in greatest profusion in the regions which have not been reached by the drift.

This anomalous distribution of the extinct mammalia appears inexplicable on the assumption that the ossiferous beds are all of postglacial age; but if they belong for the most part to interglacial times, the mode of their occurrence is precisely what might have been expected. It seems indeed impossible to resist the conclusion that at the time the mammalia frequented the lower latitudes of Europe (where their remains occur so abundantly in river-gravels and cave-deposits), and while mammoths, horses, buffaloes, and oxen roamed over northern Siberia—Scotland, Ireland, Denmark, Scandinavia and other regions of Northern Europe also supported an abundant mammalian fauna, and that the mastodon and its congeners likewise occupied what are now the wooded regions and barrens of North America. And the remains of these creatures seldom or never occur in the regions referred to, because either the deposits which once contained them have been obliterated by the action of ice, or are covered up and concealed by drift accumulations.

Hitherto no reference has been made in these papers to Mr. Croll's theory of the physical cause of changes of climate during geological epochs. That theory for the first time rendered possible the reconciliation of apparently contradictory facts. Phenomena which had refused to be explained by any number of ingenious hypotheses suddenly seemed to yield their secret, and the great "Age of Ice" appeared all at once in a new light. The results of recent research in this and other countries tend more and more to show that the indirect influence of excentricity of the earth's orbit is the prime cause of cosmical changes of climate. It was in 1864 that Mr. Croll's first paper upon this subject appeared. At that time very little was known about interglacial periods. Ramsay had already shown that as regards Britain there had been two periods of great extension of glaciers separated by an intervening age of submergence and floating-ice. Morlot had also pointed out that the morainic deposits of Switzerland gave evidence of the former existence of two ice periods, and his results had subsequently been remarkably confirmed by Professor Heer, and others.<sup>1</sup> But these later observations were certainly not generally known in Britain at the time when the theory I refer to was published. It was, however, a familiar fact that interglacial beds occurred in the till of Scotland, and from the appearance of these deposits my brother had inferred that the great ice-sheet occasionally melted away so far as to uncover

<sup>1</sup> I learn from Mr. A. E. Jörnebohm, of the Geological Survey of Sweden, that in that country there are two Till's, both of which he considers to be true *moraines de fond*. He says that "the line of demarcation between them is generally very sharp, and in some places the lower till has evidently been partly broken up, and denuded before the upper till was deposited." "These facts," he continues, "seem to point out that during the glacial period there was a great interval of comparatively mild climate, when the ice retreated to the mountain regions; the land, however, was not submerged. Freshwater and superficial deposits that gathered during that interval may have been completely destroyed by the returning ice."

some portion of the low grounds of Scotland. But certainly no English geologist had up to the appearance of Mr. Croll's first paper in the *Philosophical Magazine* ventured to affirm that the climate of these interglacial periods in this country could be other than cold or sub-arctic. Indeed, the facts then known did not warrant any such conclusion. But the publication of this ingenious theory tended to revolutionize all our previous conceptions on the subject; for, if there was any truth in the hypothesis at all, then the records of mild and even genial interglacial periods might certainly be expected to occur. The former existence of such periods followed no less surely from theory than did that of cold and arctic conditions. Mr. Croll himself had referred to the intermingling of arctic and southern mammalia in the valley-gravels as in favour of his hypothesis, an explanation of the facts which, Sir J. Lubbock remarks, at once gets rid of what has always hitherto been considered a difficulty. By many English geologists, however, the valley-gravels with extinct mammalia were, and still are, believed to be of postglacial age. Others again, as Mr. Godwin-Austen, are of opinion that these gravels in the south of England are the equivalents of the glacial deposits in the north. But as far as I am aware, no geologist has yet attempted to correlate the river-gravels with undoubted interglacial deposits. I was in hope that ere long some one well acquainted with all that pertains to the superficial deposits of England would address himself to this task; for it seems to me that a far deeper significance attaches to the interglacial deposits of Scotland, Switzerland, and America than has yet been recognized, otherwise their bearing on the phenomena of the English drifts could hardly fail to have attracted more attention. That many of the views entertained in these papers have already occurred to fellow-workers in other fields is extremely likely; some of the conclusions indeed appear too obvious to have escaped attention. Others again are novel and opposed to prevailing ideas, and these I should like to have discussed at greater length, but I have already covered too many pages of the *MAGAZINE*. I hope, however, to enter more fully into the whole subject of glacial and interglacial climates in another place. It would extend this paper (already long enough) beyond due limits were I to attempt any summary of the conclusions arrived at in this and preceding papers: the accompanying table (pp. 262, 263), however, will show the arrangement of the Quaternary deposits which has been suggested.

#### VII.—MIDDLE GRAVELS (?), IRELAND.

By G. H. KINAHAN, M.R.I.A., etc.

**I**N a paper on a comparison of the drift of Ireland with that of Lancashire, the author Prof. Hull states, that he recognized the equivalents of the English beds in the drift cliffs at Killiney, Co. Dublin,<sup>1</sup> and in the *GEOL. MAG.* for March, 1872, Mr. J. Geikie has quoted Prof. Hull: I therefore request leave to say a few words about the gravels of Ireland, more especially as Mr. Geikie

<sup>1</sup> *GEOL. MAG.*, Vol. VIII., p. 294.